



Grid Basics for Non-Engineers & for Policy Development



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Women in Energy
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A Few Important Technical Issues:

- 1) How is electricity generated?**
- 2) Historical Grid & Today's Grid**
- 3) Electrons: Voltage & Frequency**
- 4) Real Power & Reactive Power**
- 5) Supply, Demand, Generation & Over-generation**
- 6) What is “Islanding?” (Anti-islanding vs Intentional islands)**
- 7) CPUC Regulation**





A GENERATOR

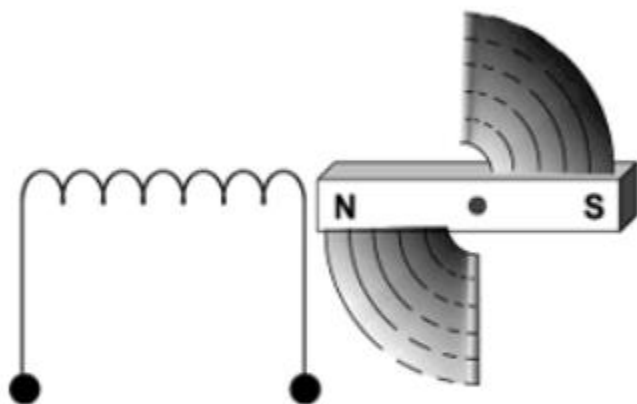


Figure 1: To generate electrical power, a coil is mounted close to a magnet that is spinning on a shaft. As the poles of the magnet sweep past the coil, voltages of alternating polarity are induced in the coil.

A SINE WAVE

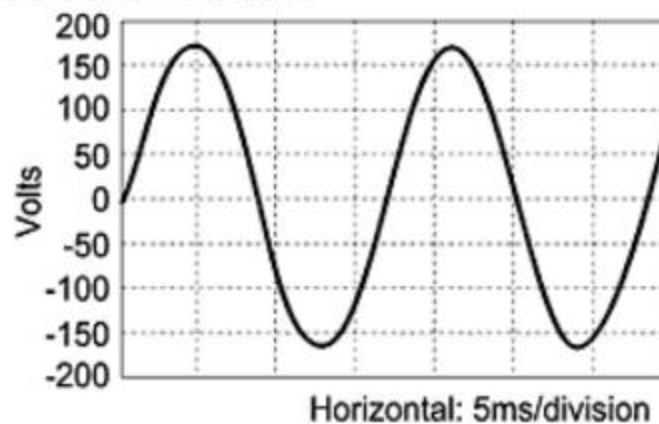


Figure 2: A 120-volt, 60-Hz generator produces power output that cyclically varies from 169.7V to -169.7V.

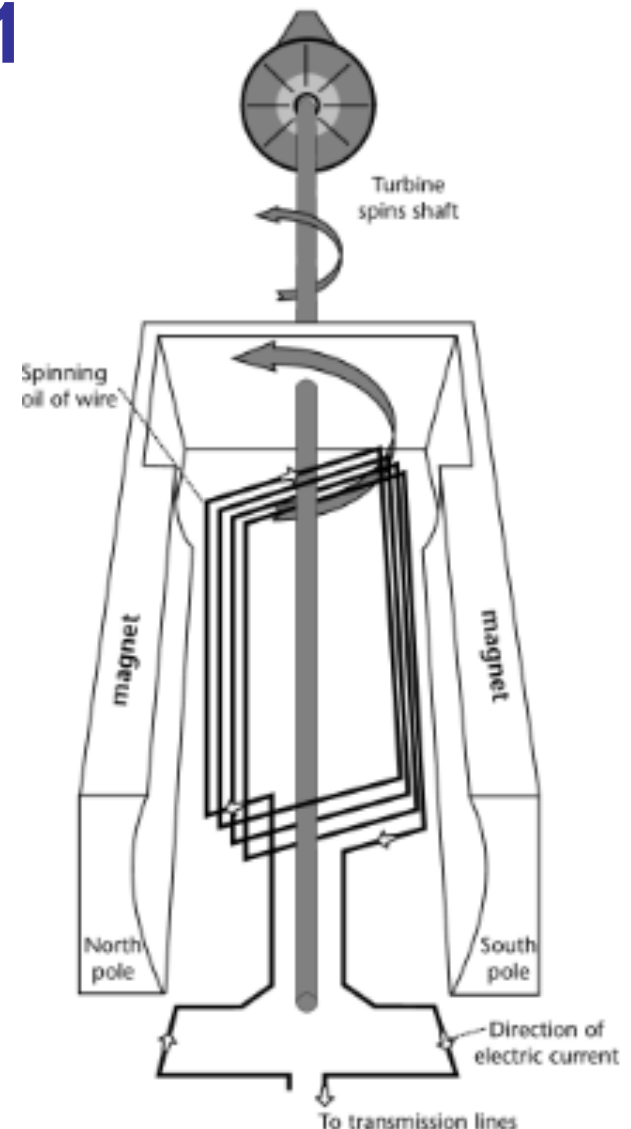




Generating Electricity 101

- There are many different sources of electricity and many different ways electricity can be produced.
 - When a magnetic field is in motion relative to a copper wire (or a conductive material) it triggers the flow of electrons in the wire, creating electricity.
- Power plants and electrical generators use large quantities of copper wiring wrapped around a shaft - called an armature - spinning inside very large magnets at very high speeds to generate electricity. [EXCEPT photovoltaic cells]
 - Most often the armature is turned by the force of water or steam!. A variety of materials can be combusted to produce steam including natural gas, nuclear fusion, fossil-fuels such as coal, wood, or other materials.

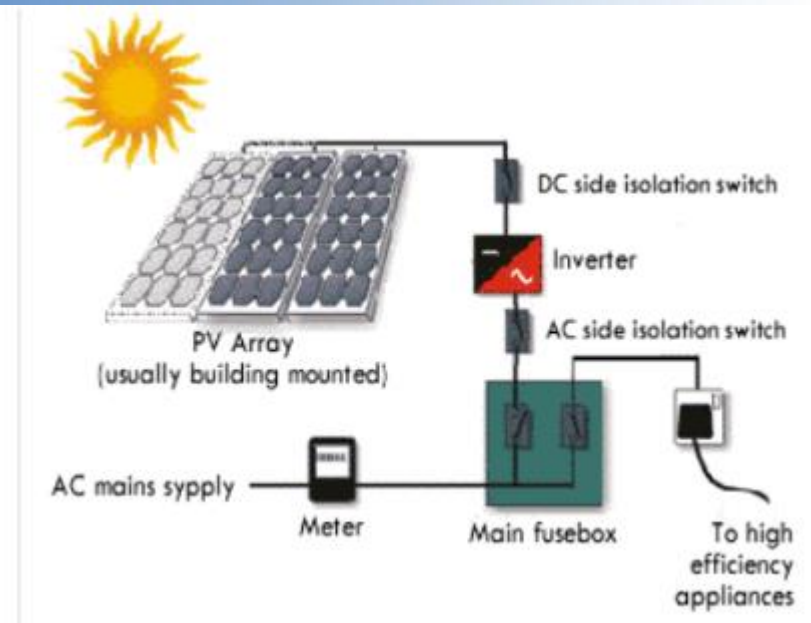
TURBINE GENERATOR





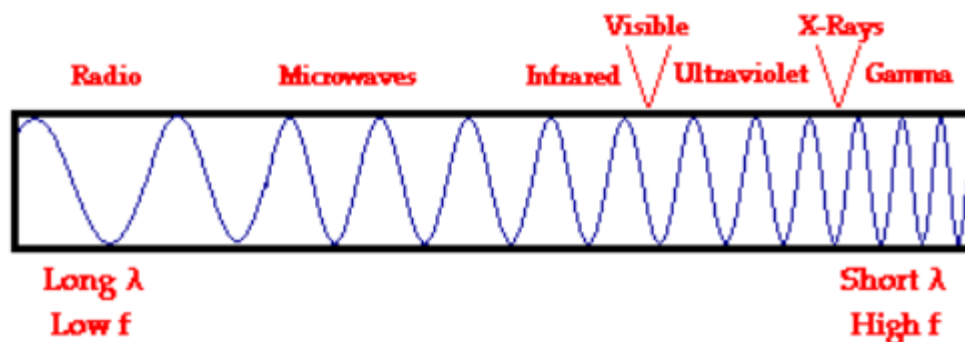
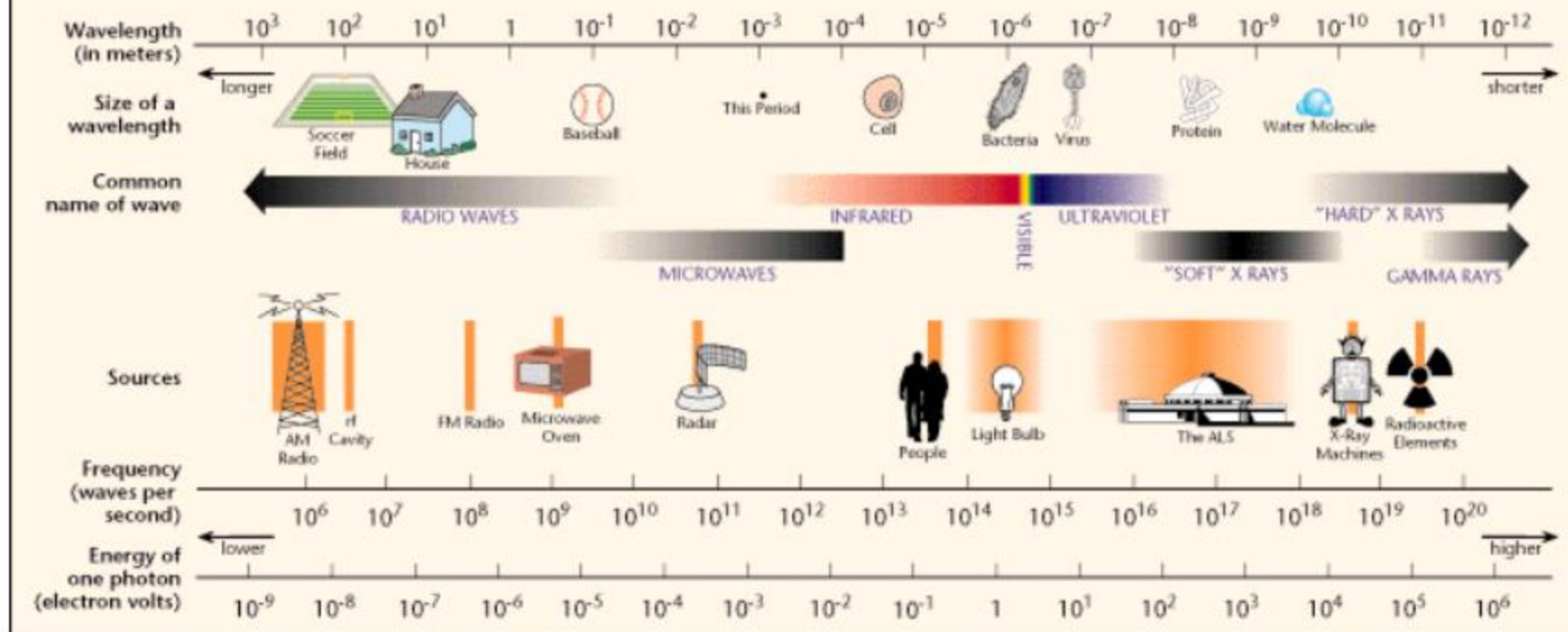
Photovoltaics

- The photovoltaic (PV) process converts free solar energy - the most abundant energy source on the planet - directly into solar power.
- A PV cell consists of two or more thin layers of semi-conducting material, most commonly silicon. When the silicon is exposed to light, electrical charges are generated and this can be conducted away by metal contacts as direct current (DC).
- The electrical output from a single cell is small, so multiple cells are connected together and encapsulated (usually behind glass) to form a module (sometimes referred to as a "panel"). The PV module is the principle building block of a PV system and any number of modules can be connected together to give the desired electrical output



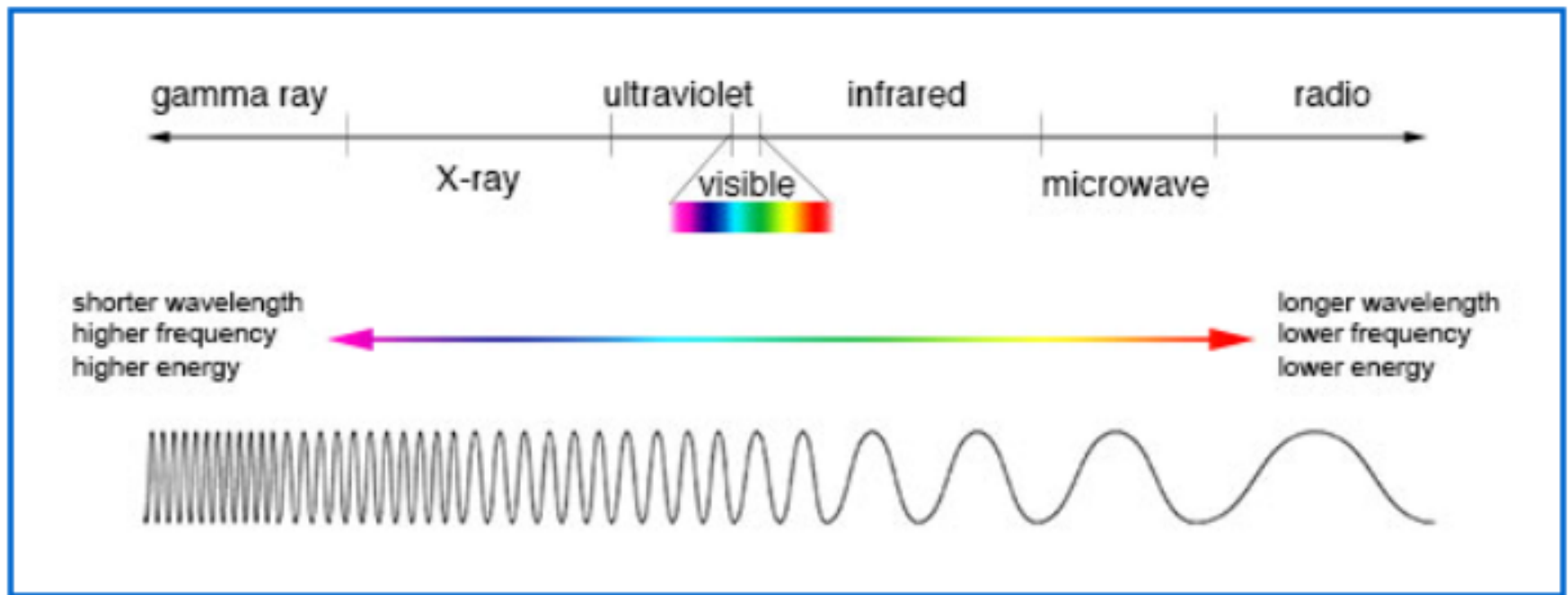


THE ELECTROMAGNETIC SPECTRUM





Solar energy harnesses Infrared, Visible Light, and UV spectrum.



Comparison of wavelength, frequency and energy for the electromagnetic spectrum.
(Credit: NASA's Imagine the Universe)



Historical Grid & Today's Grid

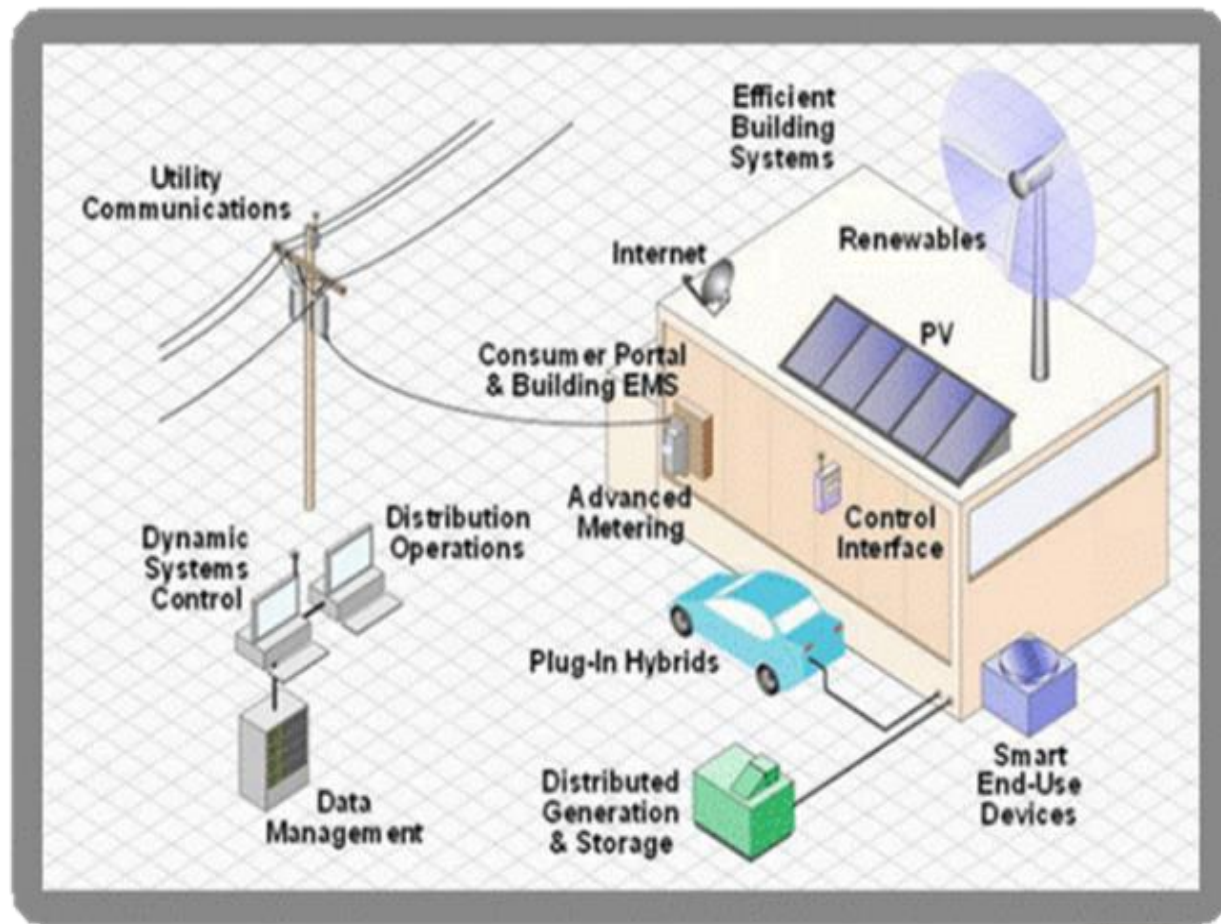
- The Grid's basic design is more than 100 years old
- 1 way flow of electrons





Today's Grid; Connecting Distributed Energy to the Distribution and Transmission Grids

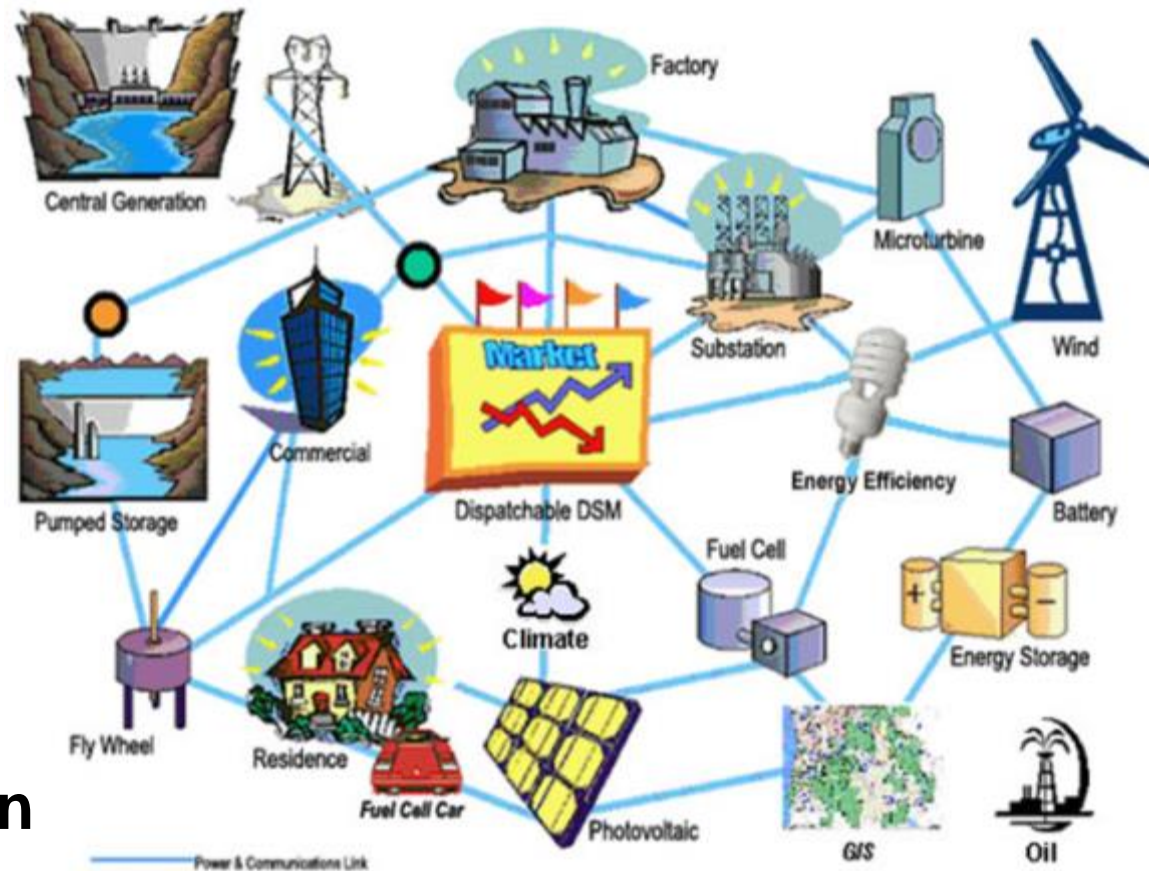
- New options!
- Behind customer meter:
- Distributed Renewables
- EVs
- Smart Devices (NEST)
- Connected to transmission and distribution grids
- Communications services connect energy resources





Distribution and Transmission Grid of the Future

- Two way flows of energy on distribution infrastructure
- Communications to energy resources provide visibility and control
- Distributed intelligence
- Increasing renewables
- Central and distributed generation
- Resilient and Self-healing design





Electricity Basics: Electrons, Voltage & Frequency

Voltage (V) & Frequency (f)

**Thank you
NREL!**

Ideal Power System

- Constant Voltage (V)
- Constant Frequency (f)
- Always available
- Power Quality Excellent



Simplistic Concepts:

Power (P)

- Controls the Frequency (f)

Reactive Power (Q)

- Controls the Voltage (V)





Voltage & Frequency; think in waves

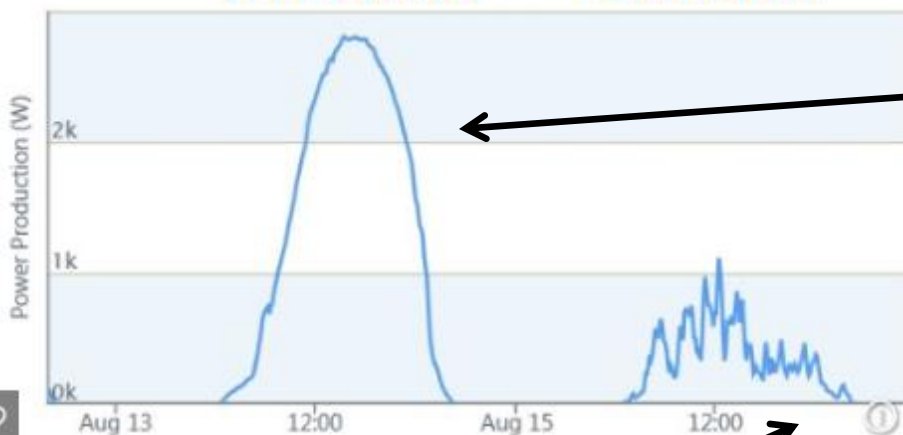
example – solar production

Sunny Day

21.4 kWh

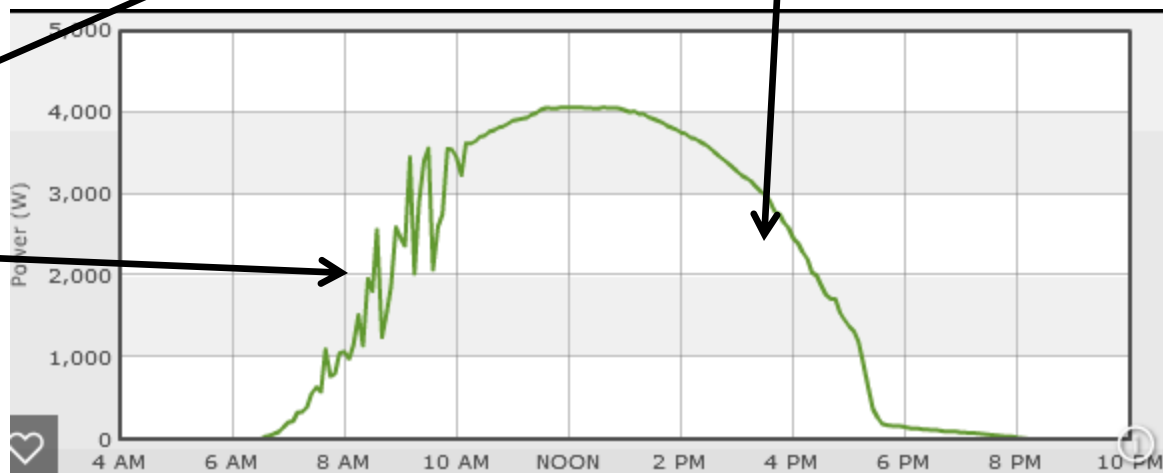
Cloudy Day

5.1 kWh



Smooth is good!

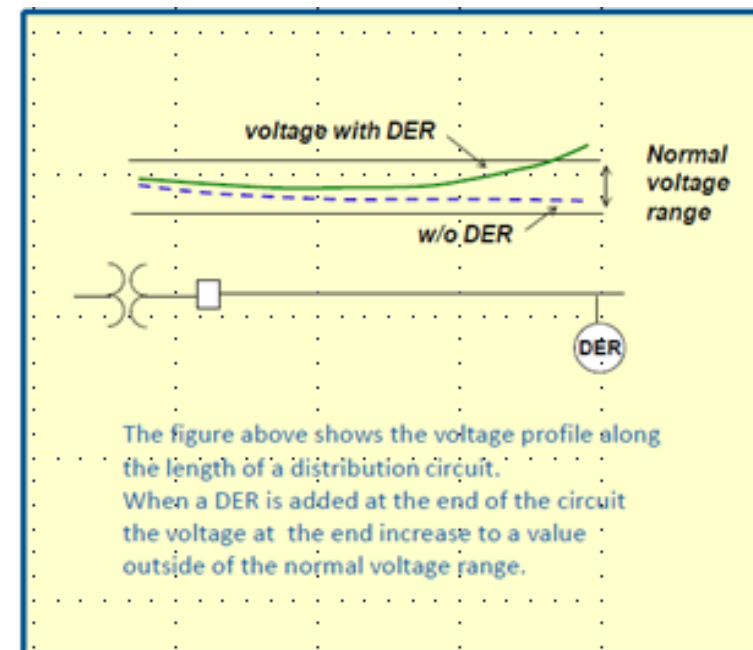
Spikey is not good!





Important ideas to remember:

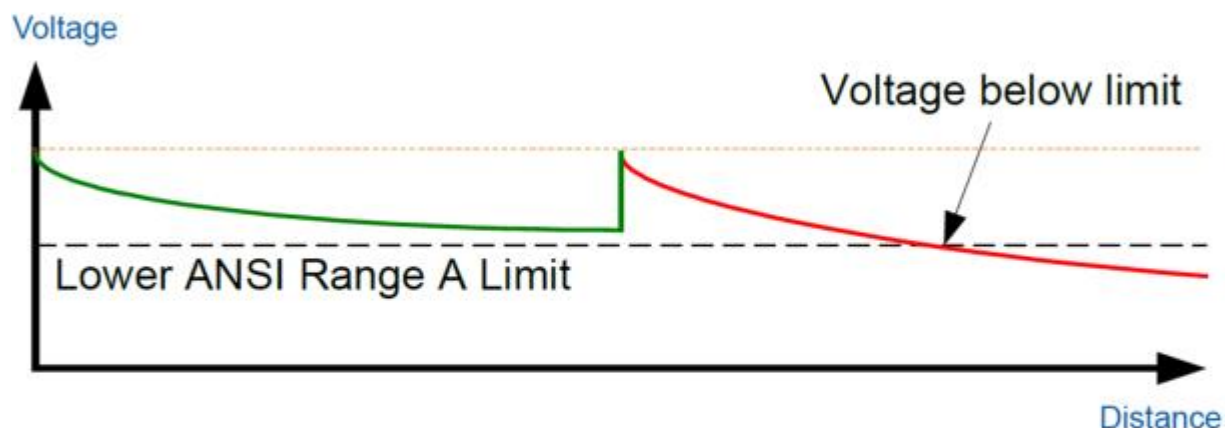
- **Frequency and Voltage must stay within appropriate bandwidth from substation all the way to the end of the circuit**
 - Utility requires protection devices to ensure that V&F stay constant for all customers
 - ***Injecting power onto the grid (e.g., solar panels producing power) impacts Voltage on the circuit. →***
 - **Or else things break!**
- DER = Distributed Energy Resource**





Voltage & Frequency must stay within limits!

Voltage Measured along a Feeder



Goal is to Maintain voltage within limits

**ANSI =
American
National
Standards
Institute**





Real & Reactive Power

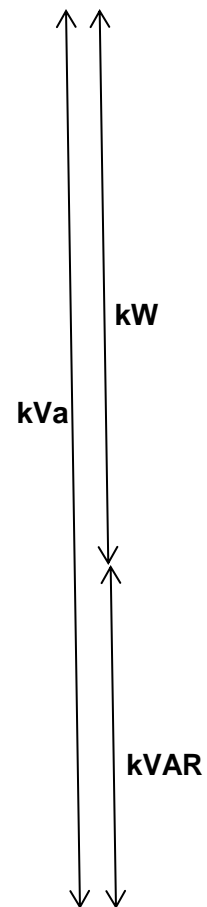
- **NEED BOTH Real and Reactive power to keep the system working**
- **Real power** = The component of electric power that performs work, typically measured in kilowatts (kW) or megawatts (MW)--sometimes referred to as Active Power.
- **Reactive power** = Reactive power exists in an AC circuit when the current and voltage are not in phase.
- Analogy: think about an ocean wave. Real power is like the energy that we see at the top of the wave. Reactive power is like the undertow that keeps the wave cycling and moving. Both real and reactive power are needed to transmit power over distance





VARs (Voltage Ampere Reactive)

Power of the Wave, It Keeps the Electrons Moving



REAL POWER

The Power of the Wave

REACTIVE POWER

Inertia for the Wave





Dispatchable vs. Non-Dispatchable

Dispatchable (easy to control and maintain voltage and frequency)

Non-Dispatchable (NOT EASY to control or maintain voltage and frequency)

Dispatchability affected by many factors including whether generation is intermittent or consistent.

Some fuel sources yield intermittent generation

- **E.g. Wind/ solar – intermittent generation, use when “available” or “lose it!”**
 - Unless Storage is incorporated
 - Resource mix can help balance dispatch needs





Supply & Demand

- **No matter the source used to produce electrons, whether renewable or fossil-fuels, the amount of energy produced and transmitted over the grid must equal the amount consumed to keep the system “in balance.”**
 - Too much supply? Too much demand? = Voltage & Frequency problems!
 - Danger, danger: Voltage collapse & Blackouts
 - Employ demand response & demand shifting strategies
 - Encourage supply at times when needed
 - Energy Storage can help





Over-Generation

- **Problem: When supply of electrons is greater than demand for electrons**
- **Strategies to avoid Blackout:**
 - Reduce generation
- **But where and what type?**
 - CAISO will always shut down generators that DO NOT produce “Reactive Power”
 - Why?
 - Long, skinny system grid requires “inertia”
 - Reactive power = inertia that keeps electrons moving
- **Reduce or shift demand**





What happens when Voltage or Frequency go outside of limits? Blackout! Great Eastern Blackout of 2003





From “Anti-Islanding” to “Intentional Islanding”

- **An electrical “island” is where electricity is coursing through the grid when it not supposed to be.**
- **The grid has been designed to prevent islands for safety reasons.**
 - Ex: If grid is down but there is a generator generating in one place, that hot wire could kill an unknowing lineman → unknown islands are BAD!





Intentional islands

- **Microgrids (like UC San Diego microgrid) designed to continue to operate even when the grid goes down.**
 - Requires modern grid design, safety protection systems including communications and visibility
- **Microgrids can increase local and system resiliency and require:**
 - Communications
 - Suites of distributed energy resources
 - Modern protection schemes
 - New regulations to enable!





CPUC Mission & Vision

- **Mission:** The California Public Utilities Commission serves the public interest by protecting consumers and ensuring the provision of safe, reliable utility service and infrastructure at reasonable rates, with a commitment to environmental enhancement, a healthy California economy, and inclusiveness. We regulate utility services, stimulate innovation, and promote competitive markets, where possible, in the communications, energy, transportation/charter party carrier, and water industries.





Thanks & Questions

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